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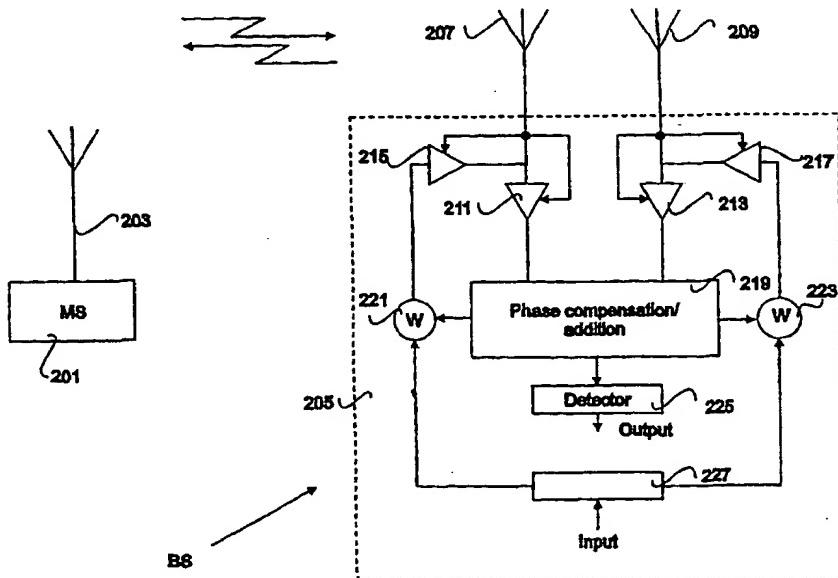
(57) Abstract

In a cellular radio system down-link diversity is provided. The system has means in a base station (BS) for receiving signals from a mobile station (MS) using a diversity reception arrangement, in particular an antenna diversity arrangement (207, 209). Information regarding the current reception conditions is extracted from the reception diversity system and is used for improving the transmission. Thereby the transmitted signals can have less signal power, which in turn makes it possible to provide smaller cluster sizes and thereby increase the channel capacity in the cellular radio system.

A METHOD AND A SYSTEM FOR DOWN-LINK DIVERSITY IN RADIO TRANSMISSION

TECHNICAL FIELD

The present invention relates to a method and a system for radio communication.

DESCRIPTION OF RELATED ART

In cellular radio systems the number of cells used for covering a particular area should be as small as possible in order to minimize the costs. However, in order to maintain a sufficiently good signal to noise ratio (SNR) for a system having many mobile stations, the cell size should be as small as possible.

Thus, using a small cell size the same signals can be reused at other locations in the cellular radio system. In a system having M orthogonal signals or channels these are usually divided into K groups having the same or close to the same number of channels. In a hexagonal cell pattern with the base station located in the middle of the cell, see Fig. 1a, K can be any integer written as

$$K = (i + j)^2 - ij, \text{ where } i,j = 0,1,2,3,..$$

Thus K can be K = 3,4,7,9,12,13,...

A group of cells where each channel group is used once is usually termed cluster. K is therefore usually termed cluster size.

It is also common to use more advanced cell structures, where the base stations use directive antennas located in the corners of the cells, see Fig. 1b. A cell structure having a cluster size of 12 and 4 base station locations per cluster is denoted a 4/12 cluster and same way a cell structure having cluster size of 21 and 7 base station locations per cluster is denoted a 7/21 cluster etc. Such arrangements have the advantage that several base stations can be located at the same location, which is cost saving. The maximal distance from the base station to a mobile station will be increased but the number of interfering closely located base stations will be fewer.

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In order to optimize the system for handling as many calls per cell as possible it is desired to have access to as many channels as possible per cell. This can be termed the capacity of the system (n), where

$$n = M/K$$

For a certain system the number of channels M which can be used is usually predetermined. Hence, in order to increase the capacity of the cellular radio system the number of groups K should be as small as possible. How small the number of groups K can be is determined by how sensitive to noise and interfering signals the signals are.

In order to increase the performance in transmission on a fading radio channel, diversity is employed. Diversity means that the same signal is transmitted via two or more transmission paths. There are many different types of diversity arrangement such as: frequency diversity, time diversity, polarisation diversity and spatial diversity etc. In spatial diversity or antenna diversity, several antennas are used when receiving the signal. It can be shown that if the distance between two antennas is sufficiently long the signals at the different antennas will be uncorrelated.

The distance required is mainly dependent on the wavelength used in the transmission. A distance of about the wavelength divided by 2 can be sufficient to reduce the correlation to acceptable levels. The longer the distance between the antennas, the less correlation. However, very long distances may not be feasible. A normal value can be about 12 - 20 times the wavelength used.

Antenna diversity has the advantage of not requiring a larger frequency range. Also the implementation of an antenna diversity arrangement is quite simple.

In cities and other areas having a large concentration of mobile stations (mobile telephones), the frequency range available is very limited in comparison to the heavy concentration of mobile

stations. In this environment frequency diversity systems and
other types of diversity system increasing the required
frequency range are not possible to use, since the number of
channels available would be to low to cope with the large number
of mobile stations. Therefore, the use of antenna diversity
systems is preferred in many cases.

The receiver can use or weigh the signals from the different
antennas in a number of different ways. The most common methods
are:

Selection diversity: The receiver chooses the signal having the
highest signal to noise ration (SNR) and uses this signal for
the signal detection.

Maximum ratio combining diversity: The receiver uses the
information from all the reception branches all at the same
time. The signals from the different branches are given a weight
which is proportional to the SNR at the respective branch. When
using the method the individual signals must have the same phase
when the addition takes place. Thus, it is necessary to
implement a phase compensation circuit. The phase compensated
and optimal weighted signal is then used as the output signal.

Equal gain combining diversity: This is a special case of the
Maximum ratio combining diversity system. Thus, in order not to
have to measure the momentary SNR in each reception branch the
weight is set constant and equal for all the branches.

Switched diversity: This is a simple method. Thus, one branch at
a time is used and switching between different branches is only
carried out when the signal envelop drops below a certain
threshold value.

The use of diversity systems is a powerful tool in order to
avoid long fading conditions.

However, the diversity systems of today cannot be used for
significantly increasing the channel capacity for cellular radio

systems. The limitation in channel capacity is an increasing
problem, since the frequency range available is limited and the
number of mobile terminals is constantly increasing.

SUMMARY
It is an object of the present invention to improve the channel
capacity for cellular radio systems. This object is obtained by
using a diversity arrangement in the base station, which makes
use of the information obtained when receiving signals in an
antenna diversity system for transmission purposes.

The radio transmission system is therefore equipped with means
in the base station for extracting information regarding the
current diversity conditions and the extracted information is
used for controlling the transmission of the down-link signals
according to a diversity (down-link) transmission scheme.

Thus, the same information used for the reception of the signal
(up-link signal) is applied in a corresponding manner for
transmission of the signal (down-link signal). This makes it
possible to use less power in the transmitted signals whereby
the cluster sizes can be reduced. This in turn results in a
larger channel capacity according to the above.

The use of such a down-link diversity arrangement therefore
provides a system operator with a tool by means of which he can
easily increase the number of mobile stations without having to
use a larger frequency range. For example it will be possible to
reduce the co-channel interference so that a 4/12 cluster will
have the same speech quality as for traditional base stations in
a 7/21 cell cluster.

BRIEF DESCRIPTION OF THE DRAWINGS
The present invention will now be described in more detail by
way of non-limiting examples and with reference to the
accompanying drawings, in which:

- Figs. 1a and 1b show hexagonal cell structures
- Fig. 2 shows a mobile station and a base station in a cellular

radio system, where the base station has a combined receiver/transmitter using a diversity arrangement.
- Fig. 3 shows a mobile station and a base station in a cellular radio system, where the base station has a combined receiver/transmitter using another diversity arrangement.
- Fig. 4 is a flow chart illustrating different steps carried out when employing a down-link diversity scheme.

DESCRIPTION OF PREFERRED EMBODIMENTS

In Fig. 2 a principal view of a cellular radio transmission system is shown. Thus, a mobile station is shown at 201. The mobile station 201 has an antenna 203 by means of which it can communicate with a base station shown at 205. The base station 205 has two antennas 207 and 209.

The base station 205 shown in fig. 2 is designed for maximum ratio combining diversity. Thus, the SNR is derived from the signals received by the antennas 207 and 209. The SNRs are used for setting amplifiers 211 and 213 to values corresponding to the measured SNRs. In other words, the receiving branch having a better SNR will be more amplified than the receiving branch having a small SNR.

The same value as is set for the amplifier 211 is at the same time set for an amplifier 215 and the same value set for the amplifier 213 is set for an amplifier 217. The amplifiers 215 and 217 form a part of the transmission circuit of the base station 205 and are also connected to the antennas 207 and 209, which thus are used both for transmission and reception of signals to/from the mobile station 201.

The output from the amplifiers 211 and 213 is fed to a circuit 219. The circuit 219 is used for phase compensation in order to give the two received signals the same phase, before they are added, which also takes place in the circuit 219.

The information derived in the phase compensation circuit 219 is also fed to phase compensation circuits 221 and 223, which are part of the transmission circuit of the base station 205.

The output from the circuit 219 is fed to a detector or
demodulator circuit 225, which provides the output from the base
station 205.

The base station is used for bi-directional communication with
the mobile station 201. Thus, when transmitting signals from the
base station 205 to a mobile station 201 the signal to be
transmitted is fed to a modulator 227. The output from the
modulator is fed on two different lines to the phase
compensators 221 and 223. The phase compensators 221 and 223 are
set according to the current phase compensation performed in the
circuit 219. The output signals from the phase compensators 221
and 223 are then fed to the antennas 207 and 209, respectively.

Thus, the antennas 207 and 209 are duplex antennas which are
used both for reception of signals and for transmission thereof.
The antennas 207 and 209 are fed with transmission signals
having the same phase compensation and the same signal strength
relation as the SNR of the currently received signals.

This arrangement will have the effect that the signals
transmitted from the base station 205 can be transmitted using a
smaller signal power, while maintaining the same SNR at the
receiving mobile station 201.

In a preferred embodiment the duplex antennas 207 and 209 are
separated by a distance equal to half the wavelength used or an
integer multiple thereof. It is also possible to use an
arrangement having more than two antennas if that would turn out
to be more useful in certain situations. For example, three or
four antennas can be used in certain applications.

Furthermore, it is not necessary that the antenna diversity used
in the base station is using a maximum ratio combining diversity
algorithm for increasing the SNR. Other antenna diversity
algorithms can also be used in the same manner. Thus, if
selection diversity (as described above) is used the
transmitting part of the base station will use the information
provided by the receiving part and send information from the

duplex antenna which is currently used for receiving signals
from a mobile station.

This is shown in fig. 3. Thus, a mobile station 301 is
transmitting and receiving signals via an antenna 303 to a base
station 305. The base station 305 has two duplex antennas 307
and 309. The antennas 307 and 309 are connected to receivers 311
and 313, respectively. The output from the two receivers 311 and
313 is connected to a logic unit 315, which is arranged to
choose the output signal from the two receivers having the
highest SNR as output signal.

The logic unit 315 also controls two switches 317 and 319 so
that only the antenna 307 or 309 which is currently used when
receiving signals is used for transmission via a modulator 321.

Thus, when the base station 305 transmits signals to the mobile
station 301 the input signal modulated in the modulator 321 is
only transmitted via the antenna 307 or 309 which currently has
the highest received SNR. In this manner, as in the case
described above in conjunction with fig. 2, a lower signal power
can be used while maintaining the same SNR at the receiver site,
i.e. the mobile station.

The idea of letting the information obtained by an receiving
antenna diversity system be used for transmission of signals is
of course not limited to the antenna diversity systems described
above, all other antenna diversity systems can be used for
obtaining the effect. In fact, the method of letting the
information provided by a receiver diversity system is not even
limited to antenna diversity systems it can equally well be
implemented in other diversity systems, such as a frequency
diversity system. In that case the frequency information
obtained by the diversity system is used for transmission
purposes, e.g. the frequency which currently provides the best
SNR is used for transmission. However, this would require that
the receiver has means for receiving at the different
transmission frequencies.

Fig. 4 is a flow chart illustrating the steps carried out in a
base station when using a down-link transmission scheme. Thus,
first in a block 401 an up-link signal is received using a
suitable diversity arrangement, e.g. an antenna diversity
arrangement. Next in a block 403 the information obtained from
the diversity arrangement regarding the up-link signal is
extracted. For example in the case when an antenna diversity
system employing selection diversity is used, the information
extracted is the which antenna/reception branch that currently
receives the signal having the highest SNR.

Thereupon the information is passed to the transmission part of
the base station in a block 405, and finally the transmission
part feeds the antenna/antennas with a down-link signal using
the information obtained from the receiving diversity system in
a block 407. In the case when the information obtained is which
antenna in an antenna diversity system that currently receives
the signal having the highest SNR (selection diversity), the
transmission part of the base station feeds that antenna with
the down-link signal.

The method and system as described herein, which uses
information derived from a diversity arrangement for receiving
an up-link signal for transmission purposes, i.e. a kind of
transmission diversity, enables use of a smaller signal power.

This is most valuable in today's cellular radio systems where
frequency is a limited resource and reuse of frequencies at
close distance is required in order to obtain a system capable
of housing the increasing number of mobile stations, such as
mobile telephones.

CLAIMS

1. A radio transmission system comprising a base station having
a receiver diversity arrangement, **characterized by** means in the
base station for extracting information regarding the current
receiver diversity conditions and means for transmitting down-
link signals according to a diversity transmission algorithm
controlled in accordance with the information extracted from the
receiver diversity arrangement.

2. A system according to claim 1, **characterized in that the**
transmission means are controlled to apply the same diversity
algorithm to the down-link signals as is currently used for
receiving up-link signals.

3. A system according to any of claims 1 - 2, **characterized in**
that an antenna diversity arrangement is used for receiving the
up-link signals.

4. A system according to claim 3, **characterized by** duplex
antennas for receiving the up-link signal whereby the down-link
signal can be transmitted using the same antennas.

5. A system according to any of claims 3 - 4, **characterized in**
that the antenna diversity arrangement comprises two antennas
for receiving and transmitting signals.

6. A system according to any of claims 3 - 5, **characterized in**
that the antennas in the antenna diversity arrangement are
separated by a distance corresponding to an integer multiple of
half the wavelength used in the transmission.

7. A method of transmitting radio signals, **characterized by** the
steps of:
- receiving an up-link signal using a diversity arrangement and
algorithm,
- extracting information from the receiving diversity
arrangement, and
- transmitting signals according to a transmit diversity
algorithm under control of the extracted information.

8. A method according to claim 7, **characterized in** that the transmit diversity algorithm used is the same as the receiving algorithm.

9. A method according to any of claims 7 - 8, **characterized in** that an antenna diversity arrangement is used for receiving the up-link signals.

10. A method according to claim 9, **characterized in** that duplex antennas are used in the antenna diversity arrangement for receiving the up-link signal whereby the down-link signal can be transmitted using the same antennas.

11. A method according to any of claims 9 - 10, **characterized in** that two antennas are used for receiving and transmitting signals.

12. A method according to any of claims 9 - 11, **characterized in** that the antennas in the antenna diversity arrangement are separated by a distance corresponding to half the wavelength used in the transmission or an integer multiple of half the wavelength.

Fig. 1a

Fig. 1b

Fig. 2

BS

MS 201

203

205

Input

Detector 227

Output 225

Phase compensation/ addition 219

W 221

W 223

211

213

215

217

207

209

Fig. 3

```
        ┌──────────────┐
        │   Receive    │
        │   up-link    │─────401
        │   signal     │
        └──────────────┘
                │
                ▼
        ┌──────────────┐
        │   Extract    │
        │  diversity   │─────403
        │ information  │
        └──────────────┘
                │
                ▼
        ┌──────────────┐
        │    Pass      │
        │  diversity   │─────405
        │ Information  │
        └──────────────┘
                │
                ▼
        ┌──────────────┐
        │ Use diversity│
        │ information  │─────407
        │for down-link-│
        │ transmission │
        └──────────────┘
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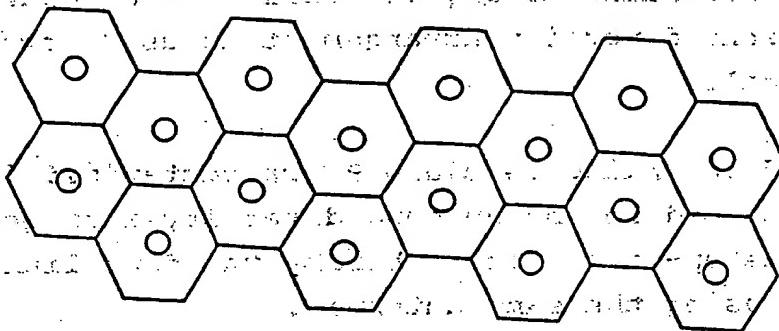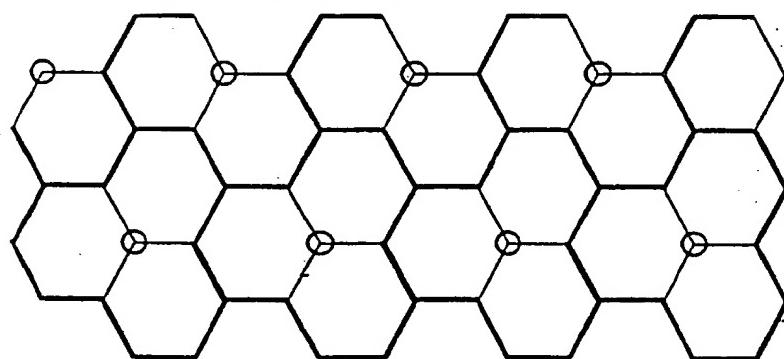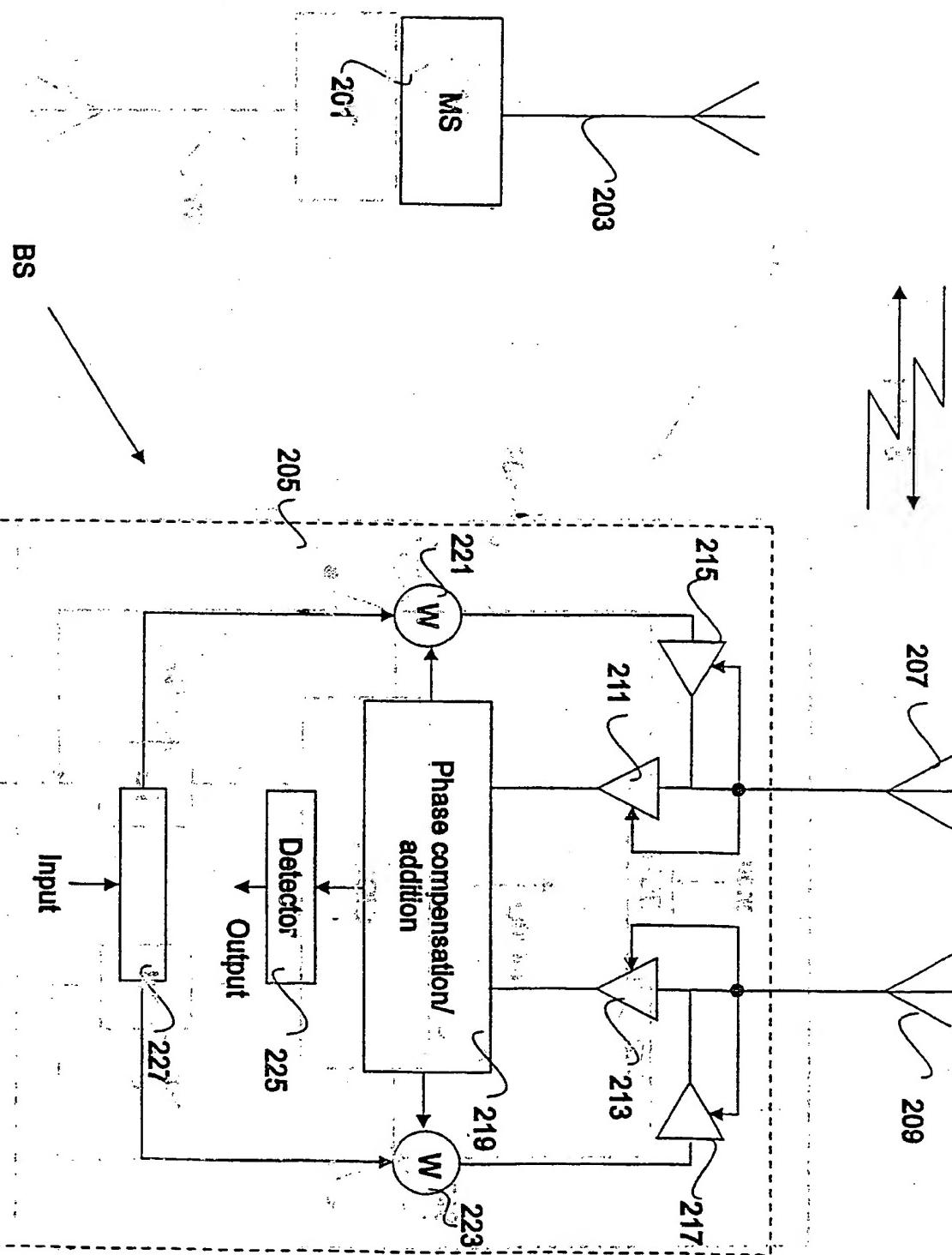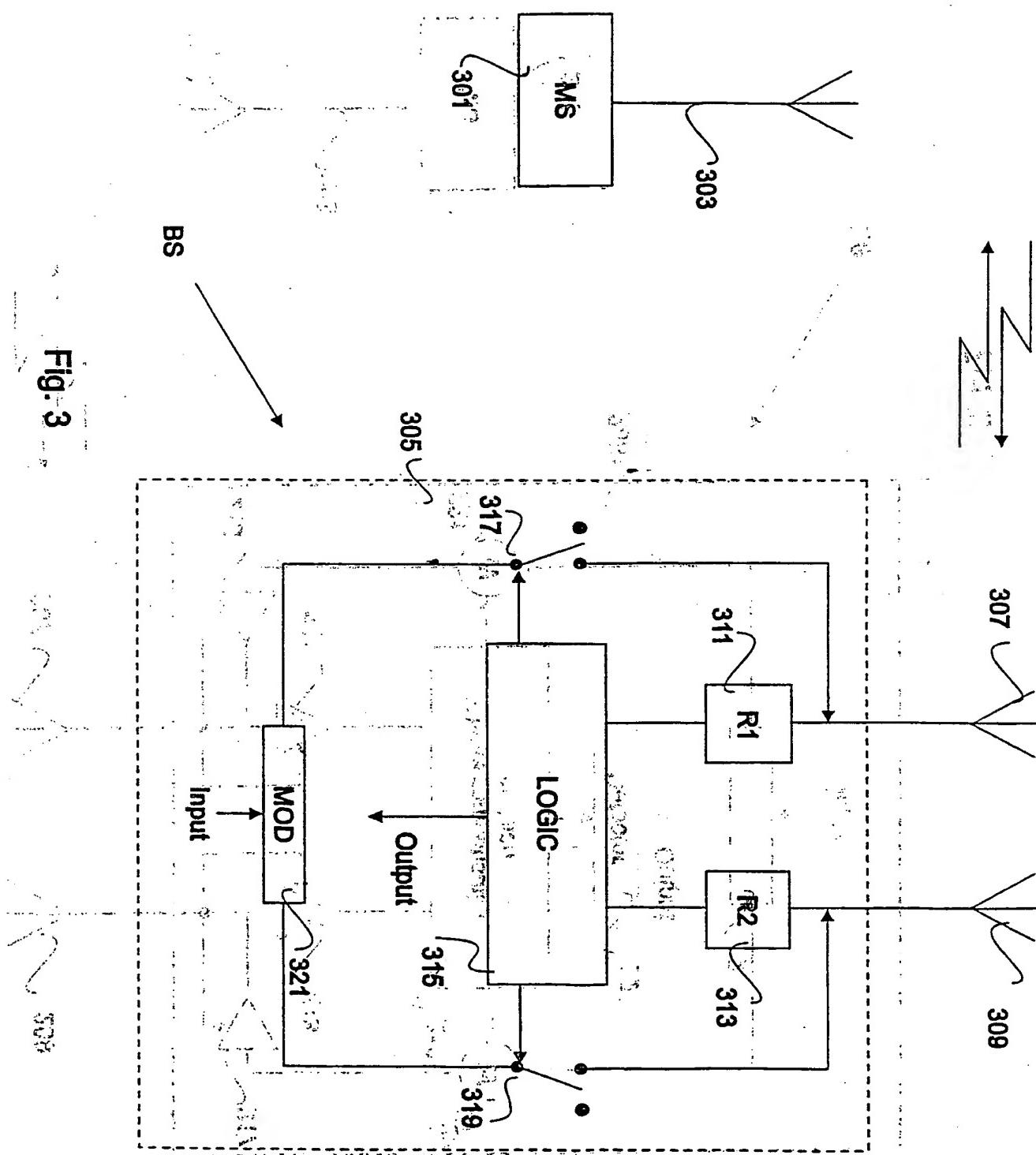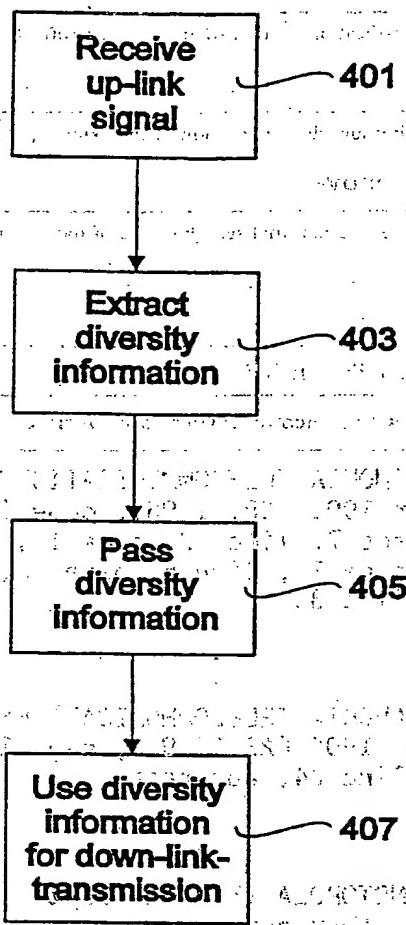
## Fig 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 99/00078

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9637974 A1 (NOKIA TELECOMMUNICATIONS OY), 28 November 1996 (28.11.96), page 6, line 8 - page 7, line 12; page 11, line 27 - page 12, line 6; page 15, line 12 - line 33	1-12
X	WO 9637973 A1 (NOKIA TELECOMMUNICATIONS OY), 28 November 1996 (28.11.96), page 15, line 18 - line 24, abstract	1-12
A	GB 2311446 A (MOTOROLA INC), 24 Sept 1997 (24.09.97), abstract	1-12

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 June 1999	30 -06- 1999

Name and mailing address of the ISA/	Authorized officer
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